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Nonlinear Static Analysis of Core Wall RCC Framed Buildings

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Abstract

RCC framed buildings mainly consists of shear walls and columns for resisting lateral force due to earthquakes. In most of the framed buildings shear walls are provided in the outer frames. In addition to shear walls provided in the outer frames, RCC lift -well (core wall) is also provided in the inner core of the buildings to accommodate lift. Core wall also acts as shear wall contributing to the lateral resistance to the buildings.
In the present study, nonlinear static analysis is performed to study the behaviour of high rise RCC buildings, the buildings have a centralised lift core wall with a door opening and shear walls in outer frames. The flange of core wall is joined together at regular interval by floor and slabs and connecting beams to provide proper connection in between flange. This Residential G+14 RCC framed building is lying in seismic zone 4 and analysed as per guidelines of is 1893 (part 1) 2016 and ETABS 17.0.1. Responses namely lateral loads, story drift, base shear, story displacement and the formation of plastic hinges compared for two types of buildings, namely with core wall and without core wall to understand the effect of core wall against the lateral loads.

Keywords: Non-linear static analysis, responses, Core wall Building, Without core wall Building, Base Shear, ETABS17.0.1

1. Introduction

High-rise buildings can be classified as residential or commercial. These days, increasingly more unpredictable elevated structures with different engineering highlights and styles are showing up. The degree of high-rise buildings demonstrates the financial aspects and innovative quality of a nation. The influence of its tallness creates different conditions and difficulties in design, construction, and operation. Accordingly, an appropriate comprehension of strategies and methods is expected of the arranging, plan, development, and activity.
One of the design criteria for choosing a basic framework in tall structures is the stability of these structures under the lateral loads. Shear walls might be utilized in interior, outer, or encompass inner assistance territories to form cores (Stafford Smith and Coull 1991).The placement and dimension are the main design parameters. Since the outer appearance of the structure can be impacted by the internal position of core walls (Stafford Smith and Coull 1991). In the early developmental phases of design, fast auxiliary examination of elective shear walls will be required trailed via cautious design and investigation of the final arrangement (Stafford Smith and Coull 1991).. Figure 1 shows single-core and multi-cell cores which are divided into two parts: (a) open core; (b) semi-open which is combined with associating beams (c) semi-open core wall with floor slabs (Stafford Smith and Coull 1991).
Due to importance of core wall technique in high-rise buildings, some researchers such as Ducan Michael et al. (1969) have studied the functioning of core wall technique. Their studies are based on structural action in torsion of the core wall in tall buildings. They found that torsional stiffness is produced by four distinct but interconnected types of action, St. Venant (C) torsion, the end warping restraints, the cantilevering push-pull effect of the channels, and any shear flow around the cell perimeter produced by beam restraints. An expression for the wall bending moments, the beam shear force, and wall displacements are calculated as per the resulting differential equation. Besides, Makoto MARUTA et al. (2000) shows the test and analytical study with results on nine H shaped reinforced concrete core walls subjected to simultaneous lateral load and torsion and based on these results the association between maximum bending moment and the maximum torsional moment is derived. They found that we have no torsional capacities and bending strength decrease when the torsional moment is less than 25%. The results of maximum bending moment and torsional moment obtain by experiment and finite element analysis were very close. The recent study conducted by Mendis (2001) showed that when a substantial torsional moment is present, value of the longitudinal stresses on the core walls due to warping and the header beam forces is quite significantly high and those actions are too large to be underestimated

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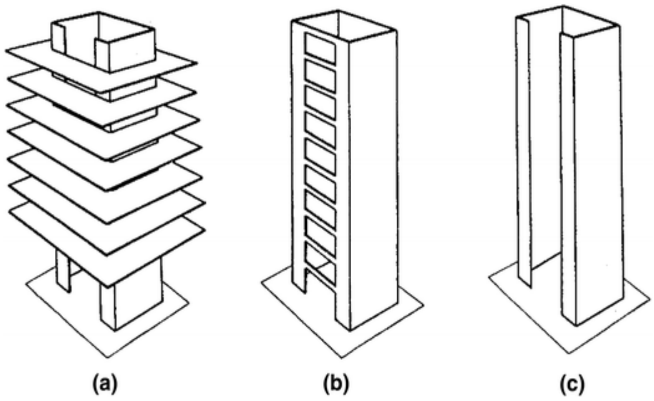

Fig 1: Types of Core Wall

In a tall structure, the core wall technique has two significant tasks. The principal task is represented by restriction on the lateral displacement by the core bending resistance and the another task is identified with limitation on the twist of the structure by torsion resistance and core warping. At any degree of core, the torque T[=T(z)] is opposed inside by a coupled Tw(z) coming about because of the shears in the flanges and related with their in-plane bending, and a couple Tv(z) coming about because of shear stresses circulating inside the section and related with the twisting of the flanges Eq. (1) (Stafford Smith and Coull 1991.).

$$T_w(Z) + T_v(Z) = T(Z)$$

Non-linear Static Analysis

Nonlinear static analysis is another name of pushover analysis in which the application of the lateral load is expanded step by step keeping up a predefined appropriation design along with the height of the framed buildings. The building is sequentially displaced till the floor reaches to the required displacement or building breakdown. The arrangement of plastic hinge formation and failure of the building is firmly watched. The correlation between base shear(Vb) and floor displacement(μN) is plotted for all the pushover analyses and to create a pushover curve.

Formation of pushover curve is the most essential part of pushover analysis. Pushover curve is also known as capacity curve. The capacity curve is the premise of the 'required displacement' estimation. So the pushover analysis might be done in two different ways: (a) the first run through till the breakdown of the structure to assess required displacement and (b) next application of required displacement to evaluate the seismic demand. The seismic demands for the earthquake (story drifts, story forces, and story displacement) are evaluated at the required displacement level. The seismic demand is then compared with the related structural capacity or predefined performance limit state to evaluate results of the structure . Independent analysis along each of the two perpendicular principal axes of the structure is allowed except a concurrent evaluation of bi-directional effects is required. The analysis results depend on the selection of the control hinge and selection of lateral load pattern. In general, the center of a mass situated at the top of

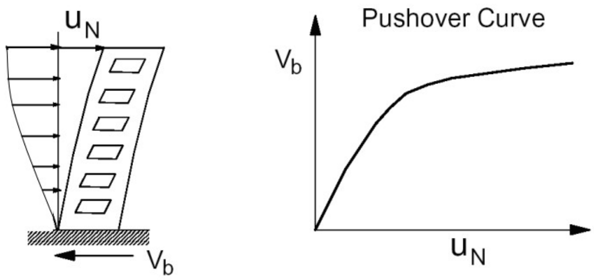

Fig 2: Representation of Pushover Curve

the structure is considered as a control node. For selecting lateral load patterns in pushover analysis, a set of guidelines is used as per FEMA 356. The lateral load is commonly applied in both positive and negative directions along with gravity load (dead load and a portion of the live load) to study the actual behavior.

In this study Responses namely lateral loads, story drift, base shear, story displacement and the formation of plastic hinges compared for two types of buildings, namely with core wall and without core wall to understand the effect of core wall against the lateral loads.

2. Modeling Details

In this study, two RCC framed buildings considered one is with a core wall and the other is without a core wall. Both models had G+14 stories, in which the height of the bottom story was 3.5 meters, and the remaining all story height was 3 meters. The total height of both buildings is 45.5 m. RC framed multi-story building has the same roof plan with 3 bays of 6m each along the longitudinal direction and along the transverse direction with Plan area 18×18 m^2. The plan and its dimensions are shown in fig 3,4,5, and 6. The lateral resisting system in model A is a shear wall at each corner and edges. The core wall is closed on having three sides and partial opening on one side. The opening area of the bottom story and the typical story is 3.5×2 m^2 and 3×2 m^2 respectively. The flange of the core wall is joined together at regular intervals by floor slabs and connecting beams to provide proper connection in between flange. The opening from the top of the core wall is 6×6 m2. The lateral resisting system in model B is a shear wall at each corner and edges but no core wall is provided at the central part of the buildings. Both Rcc framed buildings are analyzed by nonlinear static analysis.

Table 1: dimensions of buildings

1.	Building type	Residential building
2.	No. of storey	G+14
3.	Bottom storey height	3.5 m
4.	Typical storey height	3 m
5.	Total height	45.5 m
6.	Column size	550mm×550mm
7.	Beam size	400mm×600mm
8.	Thickness of slab	150mm
9.	Shear wall thickness	240mm
10.	Core wall thickness	240mm

Table 2: Seismic details of buildings

1.	Seismic zone	IV
2.	Importance factor	1
3.	Response reduction	5
4.	Soil type	2
5.	Grade of concrete	M25
6.	Grade of steel	Fe 500
7.	Dead load	1.5 KN/m^2
8.	Live load	2.5 KN/m^2

Both buildings are designed as per IS 456:2000 and analyzed as per guidelines of IS 1893(part 1): 2016. Etabs 17.0.1 software is used to perform analysis data to the buildings.

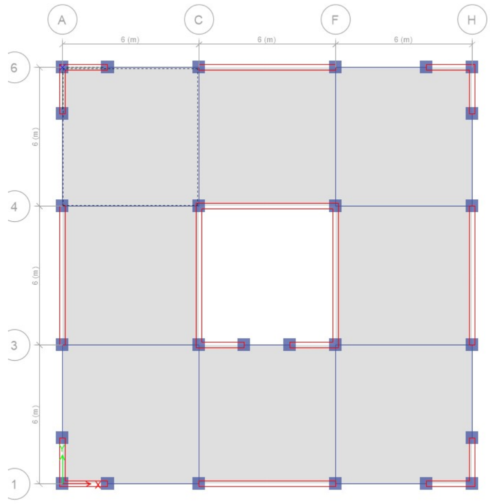

Fig 3: Plan of Core wall Building

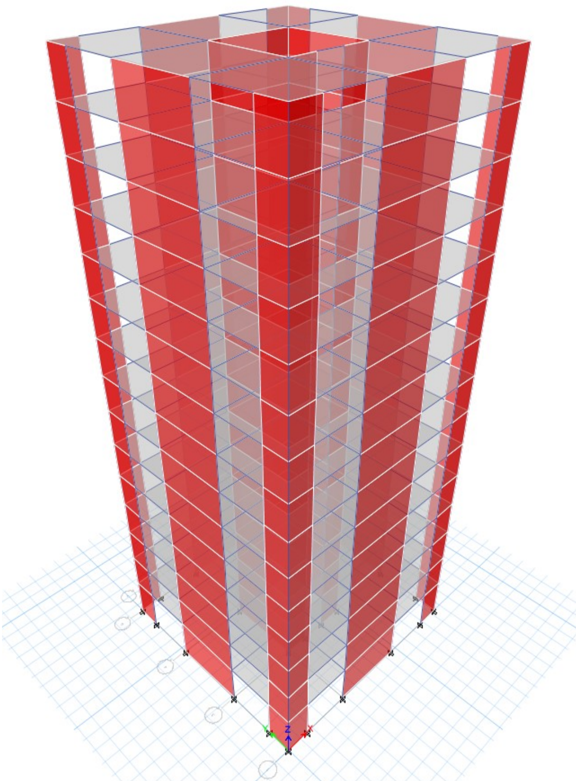

Fig 4: 3D Elevation of Core Wall Building

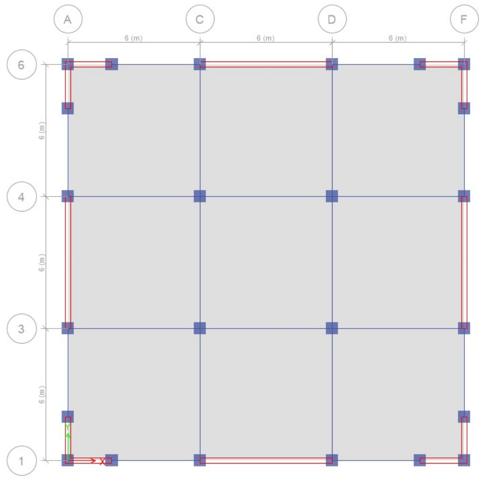

FiG 5: Plan of without Core Wall Building

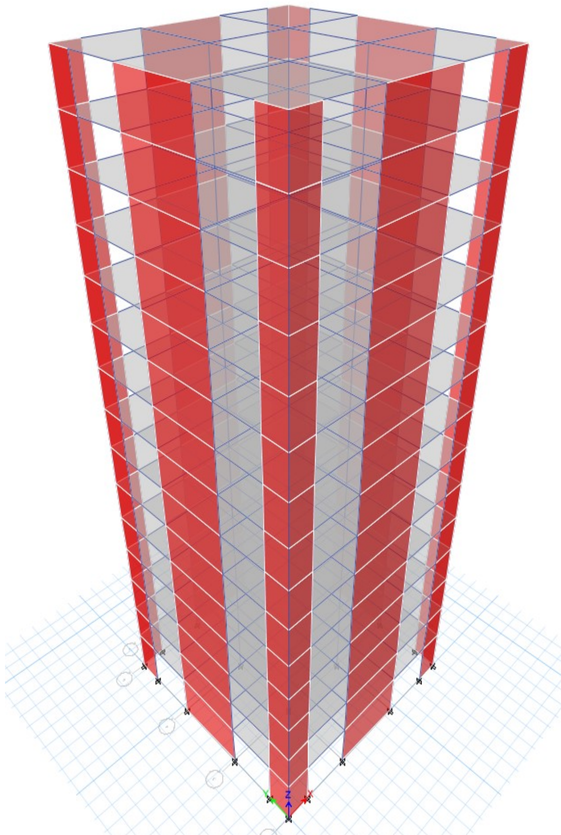

Fig 6: 3D Elevation of Without Core Wall building

3. Pushover procedure in Etabs

ETABs is used for seismic analysis and to study the behaviour of High Rise 15 storey buildings with and without core wall are compared with different aspects of analysis. Complete analysis including structural modeling is performed in this software.
The analysis and their results is obtained using ETABs 17.0.1 software by following steps:-

1. Defining dimensions of the plan.
   In this study plan of both buildings is same (18×18m^2).
2. Defining members and their material properties.

All the members of both the buildings that are beams, columns, slabs, walls, shear walls and core walls were defined as per IS 456:2000.

3. Apply loads and create loads combination. First, four loads DL, LL, EQ_X, EQ_Y were defined and there combination were developed and defined imposed loads
4. Run static analysis to check stability of both the buildings.
5. Defined pushover cases, plastic hinges and nonlinearity in loads.
6. run pushover analysis.
7. Extract results and discussion.

4. Results and Discusion

4.1 Lateral Load to Story Height

Table 3: Lateral load to story in X direction.

Story	Elevation (m)	Lateral load to Story in X direction (KN)	
		Core wall buildings	Without core wall buildings
Story15	45.5	245.999	261.1128
Story14	42.5	265.6585	265.3963
Story13	39.5	229.4775	229.251
Story12	36.5	195.9439	195.7504
Story11	33.5	165.0576	164.8947
Story10	30.5	136.8187	136.6837
Story9	27.5	111.2273	111.1175
Story8	24.5	88.2832	88.1961
Story7	21.5	67.9865	67.9194
Story6	18.5	50.3372	50.2875
Story5	15.5	35.3353	35.3005
Story4	12.5	22.9808	22.9582
Story3	9.5	13.2737	13.2606
Story2	6.5	6.214	6.2079
Story1	3.5	1.8594	1.8424
Base	0	0	0

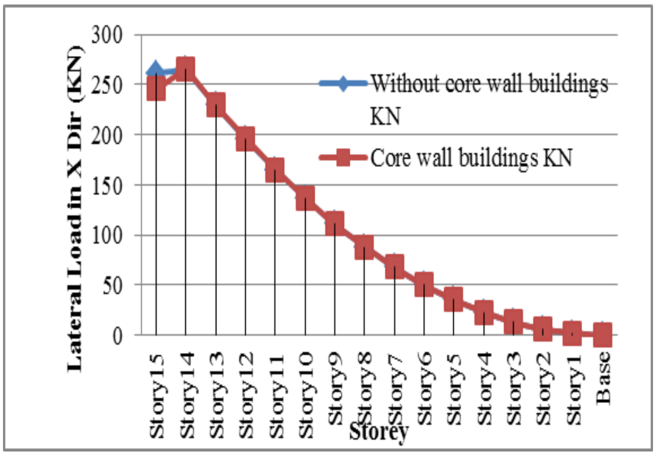

Fig 7 : Lateral load to story in X direction

Table 4: Lateral load to story in Y direction

Story	Elevation(m)	Lateral load to storey in Y dir(KN)	
		Core wall Building	Without core wall building
Story15	45.5	245.999	261.1128
Story14	42.5	265.6585	265.3963
Story13	39.5	229.4775	229.251
Story12	36.5	195.9439	195.7504
Story11	33.5	165.0576	164.8947
Story10	30.5	136.8187	136.6837
Story9	27.5	111.2273	111.1175
Story8	24.5	88.2832	88.1961
Story7	21.5	67.9865	67.9194
Story6	18.5	50.3372	50.2875
Story5	15.5	35.3353	35.3005
Story4	12.5	22.9808	22.9582
Story3	9.5	13.2737	13.2606
Story2	6.5	6.214	6.2079
Story1	3.5	1.8594	1.8424
Base	0	0	0

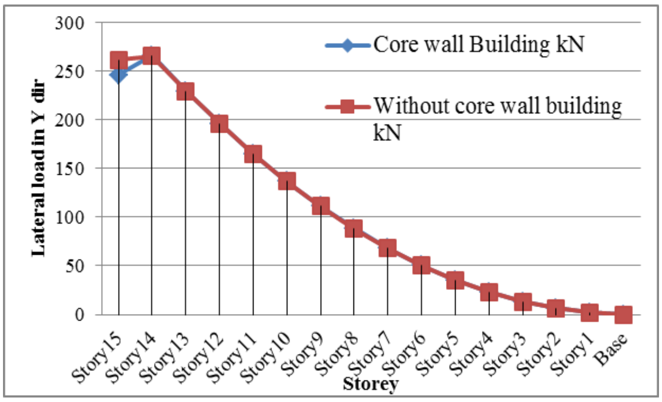

Fig 8: Lateral load to story in Y direction

4.2 Maximum Story Displacement

Maximum story displacement under push X lateral effect and constant gravity loading.

Table 5: Maximum Story Displacement

Storey	Maximum storey displacement under			
	Push X (mm)		Push Y (mm)	
	Core wall Building	Without Core Wall Building	Core wall Building	Withou Core Wall Building
Story15	15.22	19.611	14.302	19.611
Story14	14.347	18.617	13.384	18.617
Story13	13.442	17.549	12.432	17.549
Story12	12.478	16.418	11.456	16.418
Story11	11.456	15.193	10.44	15.193
Story10	10.376	13.87	9.384	13.87
Story9	9.241	12.449	8.295	12.449
Story8	8.06	10.942	7.182	10.942
Story7	6.847	9.365	6.057	9.365
Story6	5.621	7.744	4.938	7.744
Story5	4.407	6.116	3.847	6.116
Story4	3.238	4.526	2.812	4.526
Story3	2.153	3.037	1.87	3.037
Story2	1.204	1.721	1.06	1.721
Story1	0.466	0.686	0.434	0.686
Base	5.961E-06	6.807E-06	5.316E-06	6.807E-06

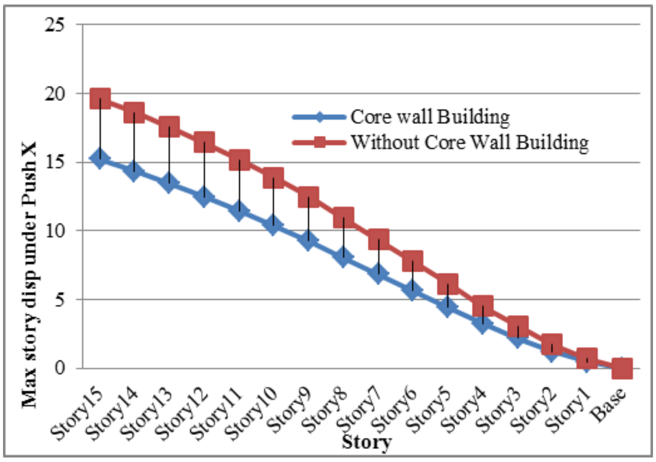

Fig 9: Maximum Story Displacement under Push X(mm)

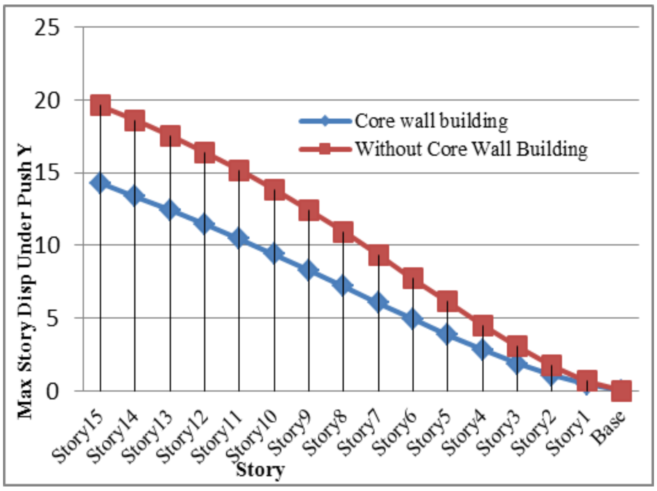

Fig 10: Maximum Story Displacement under Push Y(mm)

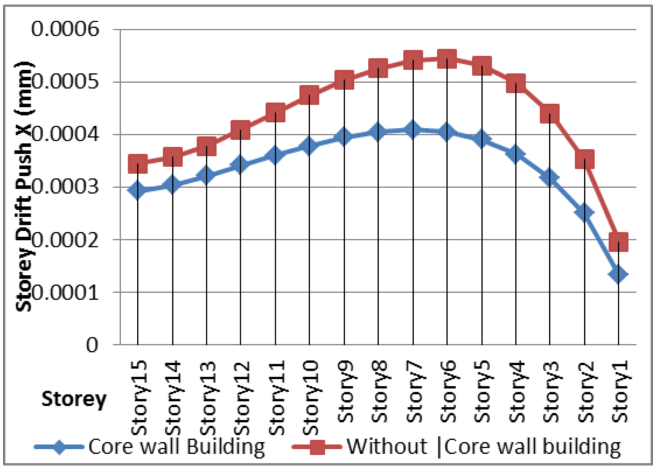

Fig 11: Maximum Story Drift Under Push X(mm)

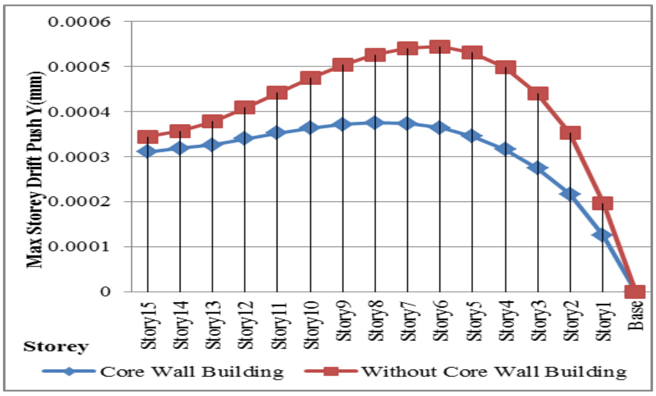

Fig 12: Maximum Story Drift Under Push Y(mm)

4.3 Maximum story Drift

Table 6: Maximum Story Drift

Story	Maximum story drift under			
	Push X(mm)		Push Y (mm)	
	Core Wall Building	Without Core Wall Building	Core Wall Building	Without Core Wall Building
Story15	0.000292	0.000344	0.00031	0.000344
Story14	0.000303	0.000357	0.000318	0.000357
Story13	0.000321	0.000378	0.000326	0.000378
Story12	0.000341	0.000409	0.000339	0.000409
Story11	0.00036	0.000441	0.000352	0.000441
Story10	0.000378	0.000474	0.000363	0.000474
Story9	0.000394	0.000503	0.000371	0.000503
Story8	0.000405	0.000526	0.000375	0.000526
Story7	0.000409	0.000541	0.000373	0.000541
Story6	0.000405	0.000544	0.000364	0.000544
Story5	0.00039	0.000531	0.000345	0.000531
Story4	0.000362	0.000498	0.000316	0.000498
Story3	0.000317	0.00044	0.000274	0.00044
Story2	0.00025	0.000352	0.000216	0.000352
Story1	0.000133	0.000196	0.000124	0.000196
Base	0	0	0	0

4.4 Pushover Curve and Hinge Formation

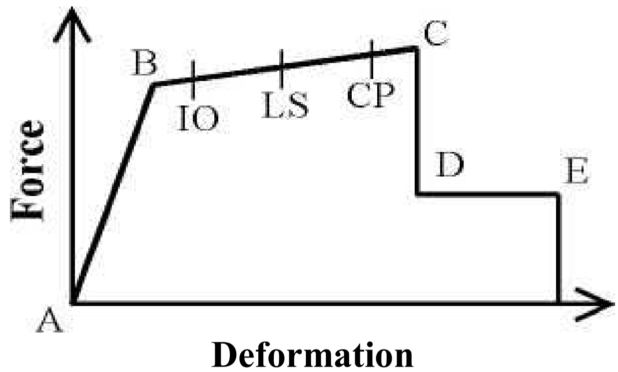

Fig 13: Pushover Curve

Table 7.1: Base Force Vs Displacement And total Hinges (Core Wall Building)(PushX)

Step	Disp (mm)	Base Force (KN)	A-B	B-C	C-D	D-E	Total Hinges
0	0	0	1545	0	0	0	1545
1	14.619	4551.8924	1544	1	0	0	1545
2	224.168	33292.2141	1100	445	0	0	1545
3	426.668	55142.5652	933	612	0	0	1545
4	433.606	55871.1262	933	610	2	0	1545

Table 7.2: Base Force Vs Displacement And total Hinges (Without Core Wall Building) (PushX)

Step	Disp (mm)	Base Force (KN)	A-B	B-C	C-D	D-E	Total Hinges
0	0	0	1500	0	0	0	1500
1	19.538	4255.734	1498	2	0	0	1500
2	220.948	23293.5839	1078	422	0	0	1500
3	406.573	36592.9454	841	659	0	0	1500
4	468.448	40796.3039	799	697	4	0	1500
5	468.799	40796.237	799	697	4	0	1500
6	469.502	40795.1276	799	697	4	0	1500
7	469.854	40800.1197	798	697	1	4	1500
8	478.539	41297.4494	792	696	4	8	1500

Table 7.3: Base Force Vs Displacement And total Hinges (Core Wall Building)(PushY)

Step	Disp (mm)	Base Force (KN)	A-B	B-C	C-D	D-E	Total Hinges
0	0	0	1545	0	0	0	1545
1	14.262	4747.463	1543	2	0	0	1545
2	195.757	34347.0928	1223	322	0	0	1545
3	398.078	60387.3938	1021	524	0	0	1545
4	471.928	69103.9079	958	581	6	0	1545

Table 7.4: Base Force Vs Displacement And total Hinges (Without Core Wall Building)(PushY)

Step	Disp (mm)	Base Force (KN)	A-B	B-C	C-D	D-E	Total Hinges
0	0	0	1500	0	0	0	1500
1	19.538	4255.7337	1498	2	0	0	1500
2	220.961	23294.002	1078	422	0	0	1500
3	400.961	36207.1888	849	651	0	0	1500
4	468.461	40796.1846	801	695	4	0	1500
5	468.813	40796.1862	799	697	4	0	1500
6	469.516	40795.0995	798	698	4	0	1500
7	469.867	40800.049	798	697	1	4	1500
8	478.78	41301.3168	793	695	4	8	1500

5. Conclusions

1. Lateral loads on both buildings are the same from both orthogonal directions of an earthquake(EQ_x and EQ_y)
2. For the same lateral loads on both buildings, Core wall building shows less story displacement under both the nonlinear effect of Push X and Push Y comparative to without core wall building.
3. Story drift in middle stories of both the building is more compare to the top and bottom stories but in that case, also core wall building shows less drift rather than without core wall building.
4. Base force Vs displacement that is used to draw pushover curve shows core wall buildings take more load and cause less displacement at each steps of the pushover analysis to compare to without core wall building.
5. In the core wall building total hinges are more and hinges lie only up to C-D zone means a sudden reduction in load resistance that can be strengthen by retrofitting method. Without core wall building, hinges lie upto the D-E zone means reduced ressistance zone.
6. Hence, building with centralised core wall with shear walls at the outer periphery of the building is more earthquake resistance than without core wall building.

Disclosures

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6. References

1. Duncan Michael, "Torsional Coupling in Core Walls in Tall Buildings." The Structural Engineer NO 2 ,Vol. 47, Feb. 1969.
2. Stafford Smith B, Coull A (1991) Tall building structures: analysis and design. Wiley, New York.
3. Makoto MARUTA, Norio Suzuki, Takashi Miyashita and Takamasa Nishioka ,"Strutural Capacities of H Shaped RC Core Wall Subjected to Lateral Load and Torsion." 12th World Conference on Earthquake Engineering, Auckland, New Zealand, 2000.
4. Mendis Priyan (2001) Warping analysis of concrete cores. Struct Des Tall Build 10:43–52.
5. Prestandard and Commentary for the Seismic Rehabilitation of Buildings: Federal Emergency Management Agency (FEMA)-356.
6. ATC-40(1996): Seismic Evaluation and Retrofit of Concrete Buildings.
7. IS 1893(Part 1) 2016: Criteria for Earthquake Resistant Design of Structures.
8. Is 875(part 2)1987:Code of Practice for Design Loads.
9. IS:456: 2000 Plain and Reinforced concrete.
10. ETABS 2017. Integrated software for Structural analysis,Design and Drafting of building system. Computers and Structures,Inc, Berkley, Version17.0.1, 2017